Choice of survey platforms and technique for broad-scale monitoring of kangaroo populations

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ABSTRACT

The commercial harvesting of kangaroos requires the regular monitoring of populations using a technique that is precise and reasonably accurate. Because of the broad distribution of the species and the generally large management areas, wildlife authorities rely on some form of aerial survey to estimate both relative and absolute kangaroo densities. Methodology for fixed-wing aircraft was developed in the 1970s and has generally become standardized in areas where it is applied. The technique allows for broad-scale coverage of management areas and involves flying at a set height, speed and direction and counting in fixed (generally 200 m) strips. An alternative method using a different survey platform (helicopter), sampling procedure (monitor block) and survey technique (line transect) has been developed recently. The technique has advantages over the standard fixed-wing survey method in accuracy, species applicability and repeatability with disadvantages in cost, time taken and in coverage of overall spatial variation. Other issues related to the benefits and drawbacks of the two methods are discussed.

INTRODUCTION

The management plans for kangaroos in states that commercially harvest the species are generally based on three separate tenets. These are, firstly, the conservation of the species involved; secondly, the ecologically sustainable use of the species; and thirdly, the mitigation of the adverse effects the species have on other land use practices (e.g., Anon. 1997).

All three aims require the estimation of population size and, therefore, management programmes require the implementation of monitoring programmes that are both precise (i.e., variations in estimates closely follow variations in population size) and accurate (close to the true population size). Because of the scale on which management programmes for kangaroos need to be implemented and the inherent problems of ground based vehicle surveys (Southwell 1989; Southwell and Fletcher 1990), the direct surveying of populations for management purposes requires the use of aircraft. Issues of estimator precision and accuracy are dealt with in more detail elsewhere (Pople 1999; Cairns 1999). In this paper I discuss aspects of the choice of survey platform and technique for broad scale surveying of kangaroos.

From a survey point of view, kangaroos present a significant challenge because of the range of habitat types that they inhabit and the general desire by agencies to develop a technique that will handle all harvested species simultaneously. The kangaroos' distributions cover large areas that are very heterogeneous with respect to vegetation cover. Canopy density varies from very open to very closed, which significantly affects the sightability of animals, with the ability to detect individuals declining as cover becomes heavier (e.g., Southwell 1989) (Figs 1, 2).

STANDARD FIXED-WING SURVEY METHODOLOGY

Since the development of aerial surveys of kangaroos in the mid 1970s, the technique has been widely applied and a standard method has evolved. A high wing Cessna-type plane is flown at a height of 250 ft (76 m) above ground level and an approximate ground speed of 100 knots (185 km h^{-1}) with a 200 m strip being scanned on each side of the plane by trained observers (Fig. 3). To convert the strip counts to estimates of absolute numbers, correction factors were developed which attempted to adjust for changing sightability related to habitat. Other correction factors are also used to adjust for temperature-related changes in animal behaviour affecting detection. Full details of the method are given in Caughley and Grigg (1982).

Wildlife authorities throughout Australia have relied on this standard fixed-wing technique to estimate kangaroo densities (Pople and Grigg 1998). It has long been known that the technique returns estimates that are unreliable in areas that are not uniformly open (e.g., Barnes *et al.* 1986) and this is the case in many of the areas where

Figure 1 (above). A moving red kangaroo in open cover is relatively easy to detect from the air. *Photo by L. A. Beard.*

Figure 2 (right). Mallee country in the south-east of the South Australian pastoral zone. A preference for such dense vegetation means that grey kangaroos are often less visible than red kangaroos. *Photo by A. R. Pople.*

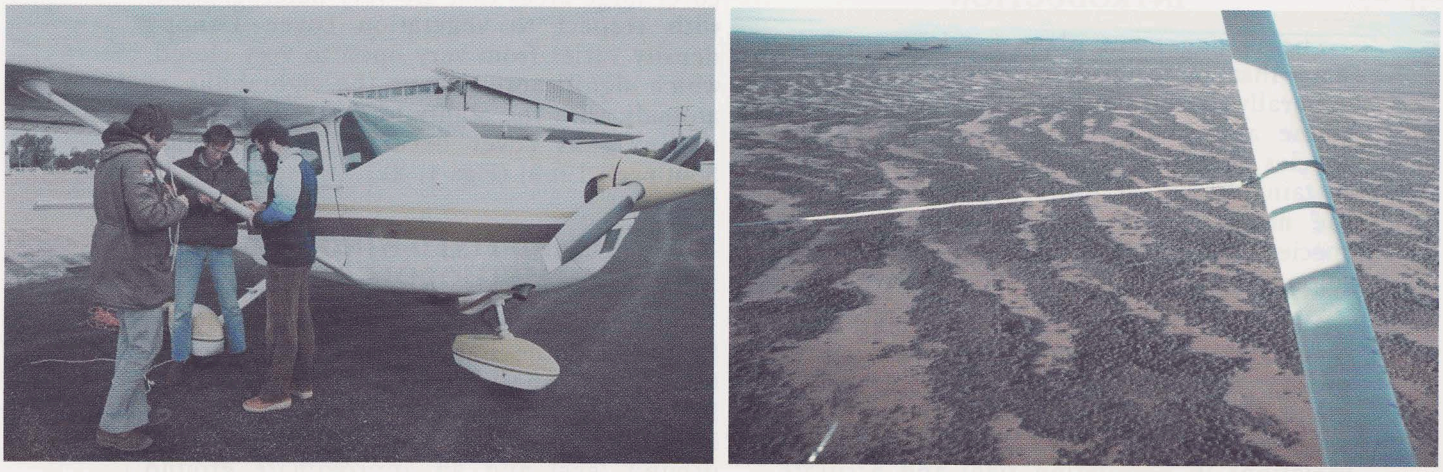


Figure 3. (a: left) Streamers being attached to the wing struts of a fixed-wing aircraft for the first aerial survey in South Australia in 1978. (b: right) These delineate 200 m wide strips on the ground. The ground in this photo is the Mundi Mundi plain north-west of Broken Hill. *Photos by G. C. Grigg.*

kangaroos (especially the two species of grey kangaroo) occur. Also, its utility as a survey method for wallaroos is questionable given the large correction factors that need to be applied to adjust for sightability bias (Short and Hone 1988; Pople *et al.* 1998).

HELICOPTER LINE TRANSECT METHOD

An alternative technique for surveying macropod populations, employing a different survey platform, a helicopter, and a different sampling and analytical approach, line transect as opposed to fixed strip width methods, has been developed by the Queensland Department of Environment and Heritage (Clancy *et al.* 1997). Helicopters have been used extensively in wildlife management programmes for large animals in North America. They are often preferred over fixed-wing aircraft because speed and altitude can be altered to achieve improved sightability under a wide range of conditions (Kufeld *et al.* 1980; Beasom *et al.* 1981; Stoll *et al.* 1991).

The technique employed in Queensland to count kangaroos involves surveying from a Bell 47 KH4 helicopter (or similar aircraft) with the doors removed and flown at 200 ft (61 m) above ground with a ground speed of 50 knots (93 km h^{-1}). Two observers sit in the

rear seat and count kangaroos from either side of the aircraft. Sightings are placed into 25 m distances classes, up to 125 m perpendicular to the transect line and recorded on to a micro-cassette recorder. An aluminium pole is used to delineate distance classes (Fig. 4).

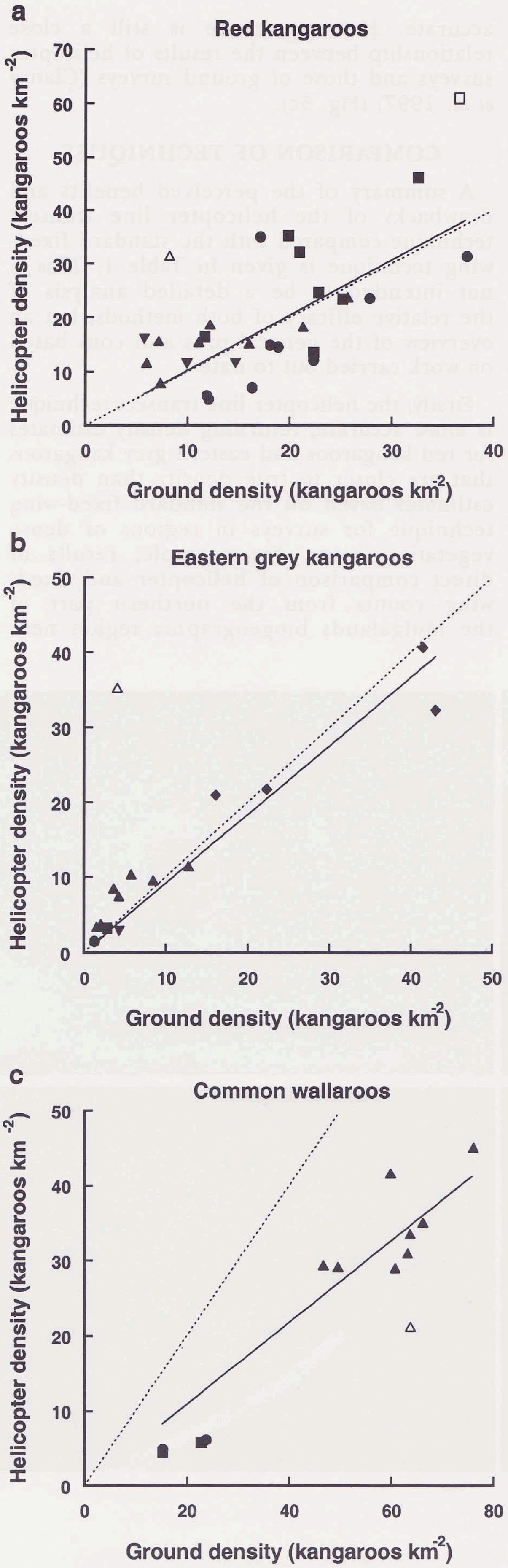
Observers count for 5 minutes continuously, and then have a 30 second break before resuming counting. Transect lines are placed 10 km apart in an east-west direction across the survey block being monitored. A global positioning receiver is used for navigation. Surveys are undertaken in the early morning and late afternoon when kangaroos are more active. Details of the analytical methodology for line transect counts are given in Burnham *et al.* (1980) and Buckland *et al.* (1993).

The helicopter line transect technique is both accurate and precise in determining population densities of eastern grey kangaroos and red kangaroos over a range of habitats, seasons and densities (Clancy *et al.* 1997; Clancy and Pople, unpubl. data) (Fig. 5a,b). For common wallaroos, the method is less accurate. However, there is still a close relationship between the results of helicopter surveys and those of ground surveys (Clancy *et al.* 1997) (Fig. 5c).

COMPARISON OF TECHNIQUES

A summary of the perceived benefits and drawbacks of the helicopter line transect technique compared with the standard fixed-wing technique is given in Table 1. This is not intended to be a detailed analysis of the relative efficacy of both methods, but an overview of the general pros and cons based on work carried out to date.

Firstly, the helicopter line transect technique is more accurate, returning density estimates for red kangaroos and eastern grey kangaroos that are closer to true density than density estimates based on the standard fixed-wing technique for surveys in regions of dense vegetation cover. For example, results of direct comparison of helicopter and fixed-wing counts from the northern part of the Mulgalands biogeographic region near



Blackall in 1991 found that the corrected standard fixed-wing counts were only around 2/3 of the helicopter line transect counts (0.65 for eastern grey kangaroo counts and 0.60 for red kangaroo counts) based on comparisons of 12 × 50 km transect lines (T. F. Clancy and A. R. Pople, unpubl. data).

Repeatablity of the fixed-wing counts is also lower, with the standard fixed-wing technique in some instances returning similar estimates to helicopter line transect, but in other cases very much lower (Pople *et al.* 1998; T. F. Clancy and A. R. Pople, unpubl. data). For example, Table 2 shows a direct comparison of density estimates of eastern grey kangaroos on eight × 50 km transect lines in the Goondiwindi area. Note the large variation in estimates returned by the fixed-wing counts. In some instances, similar results were returned for both techniques, while in other cases the estimates differed substantially (Table 2). For surveys carried out at a larger scale, variability of bias may even out especially in the case of red kangaroos (e.g., Pople 1999).

The cost of the helicopter line transect counts is much higher per sample unit than for the standard fixed-wing. The hourly operating cost of a helicopter is around double that of a fixed-wing aircraft and, as the survey speed is half, a helicopter line transect survey is approximately four times more expensive than a standard fixed-wing survey (Table 1). Also, the operating range of helicopters is generally less than a fixed-wing aircraft because of the relative fuel loads each type of aircraft can carry. This means that a different approach to sampling must be used in the case of helicopter line transect surveys, with survey blocks being sampled at high intensity rather than blanket coverage of the State with a low sampling intensity (Lundie-Jenkins *et al.* 1999). For estimating a total population for the state it means that precision may be less because sample coverage is less. The degree to which this is a problem will be related to how representative the sample blocks are of the overall survey area.

The need for shorter survey duration has both positive and negative elements. Observer fatigue is much less of a factor in helicopter

Figure 5 (left). Relationship between densities of (a) red kangaroos, (b) eastern grey kangaroos and (c) common wallaroos determined by helicopter counts (y) and ground (walked) counts (x). Fitted regression lines are shown as solid lines. The expected relationship $y = x$ is shown as a dotted line. Symbols refer to properties in central-western and southern Queensland. Open symbols are points treated as outliers. (After Clancy *et al.* 1997).

Table 1. Comparison of standard fixed-wing aerial surveys using habitat (Caughley *et al.* 1976) and temperature (Caughley 1989) correction factors with helicopter line transect surveys for the estimation of regional densities of kangaroos. RK, red kangaroo; EGK, eastern grey kangaroo; WGK, western grey kangaroo; CW, common wallaroo.

Issue	Standard fixed-wing	Helicopter line transect
Accuracy	Accuracy for RK good especially in open habitat, poor for other species	Good accuracy obtained for RK and EGK, underestimates for CW although bias relatively consistent, unknown for WGK
Precision (spatial variation)	Survey design allows for good spatial coverage (i.e., reasonable)	Costs constrain ability to fully capture spatial variability
Precision (temporal and spatial repeatability)	Stability of bias across time and space poor to reasonable	Technique robust against changes in sightability related to habitat, seasonal conditions and density for all species
Cost	$200–250 per hour surveying	$350–500 per hour
Survey speed	100 knots; allows for greater survey coverage	50 knots; makes species identification easier
Survey duration	4–5 hours; surveys more cost effective	2–3 hours; less problems with observer fatigue
Survey breaks	7 seconds every 97 seconds	30 seconds every 5 minutes
Observer comfort	Air sickness more of a problem	Can be extremely cold, very noisy conditions
Visibility	Poor to good	Excellent
Species applicability	Technique developed primarily for RK, but can be used for other species	All large macropods can be surveyed, also can collect information on a range of other species
Historical information	Long (up to 20 years) data sets exist for some areas	Technique only used regularly in one State and only since the early 1990s
Population modelling	Some limitations especially for EGK, WGK and CW	Better regionally-based models should be able to be built
Data recording	Pencil and paper	Tape recorder
Safety	Good track record for kangaroo surveys	Perceived to be less safe

line transect surveys than standard fixed-wing surveys so counting efficiency is probably higher. However, more days of survey are needed to survey the same area which adds to the cost. Similarly, the lower survey speed of the helicopter line transect technique is advantageous from the point of view of counting efficacy (Table 1). Most beneficial is the fact that animals tend to flush as you pass over them, whereas the aircraft is often well past the animal before it moves in a fixed-wing survey. The lower speed and better visibility mean that species identification is very much easier for an observer using the helicopter line transect method compared with the standard fixed-wing technique. This is an important consideration in surveys of areas where more than one species is abundant. Two or three species can occur sympatrically over substantial areas of kangaroo management zones.

The helicopter line transect technique has broader species applicability because of its ability to better compensate for sightability differences related to species, habitat and seasonal conditions. The sightability curves of the different species of macropod are markedly different; a phenomenon that line transect methods can cope with better than fixed strip-width counts (Fig. 6a). Until now the standard fixed-wing technique has treated red kangaroos and eastern grey kangaroos as equivalent, adjusting only by broad habitat class. Relative to the standard fixed-wing method, the helicopter line transect technique makes only a few fixed assumptions regarding sightability. Shapes of detection curves change from year-to-year in the same region (Fig. 6b). Also, for each species there may be marked variation in sightability from area-to-area, which the helicopter line transect technique is better at dealing with.

Table 2. Comparison of density estimates (numbers per km^2) for eastern grey kangaroos returned by helicopter line transect (LT) surveys and standard fixed-wing surveys in strip transects (ST) using habitat (Caughley *et al.* 1976) and temperature (Caughley 1989) correction factors. See text for details.

Transect	Helicopter LT	Fixed-wing ST	Per cent difference
1	34.43	3.78	–89.0%
2	20.01	6.54	–67.3%
3	41.77	22.12	–47.0%
4	17.01	8.15	–52.1%
5	17.79	5.12	–71.2%
6	31.10	4.05	–87.0%
7	21.08	22.39	+6.2%
8	22.99	7.99	–65.2%
Mean	25.77	10.02	–61.1%
CV	11.51	25.50	+121.5%

From an observer comfort point of view, helicopters have the advantage in stability

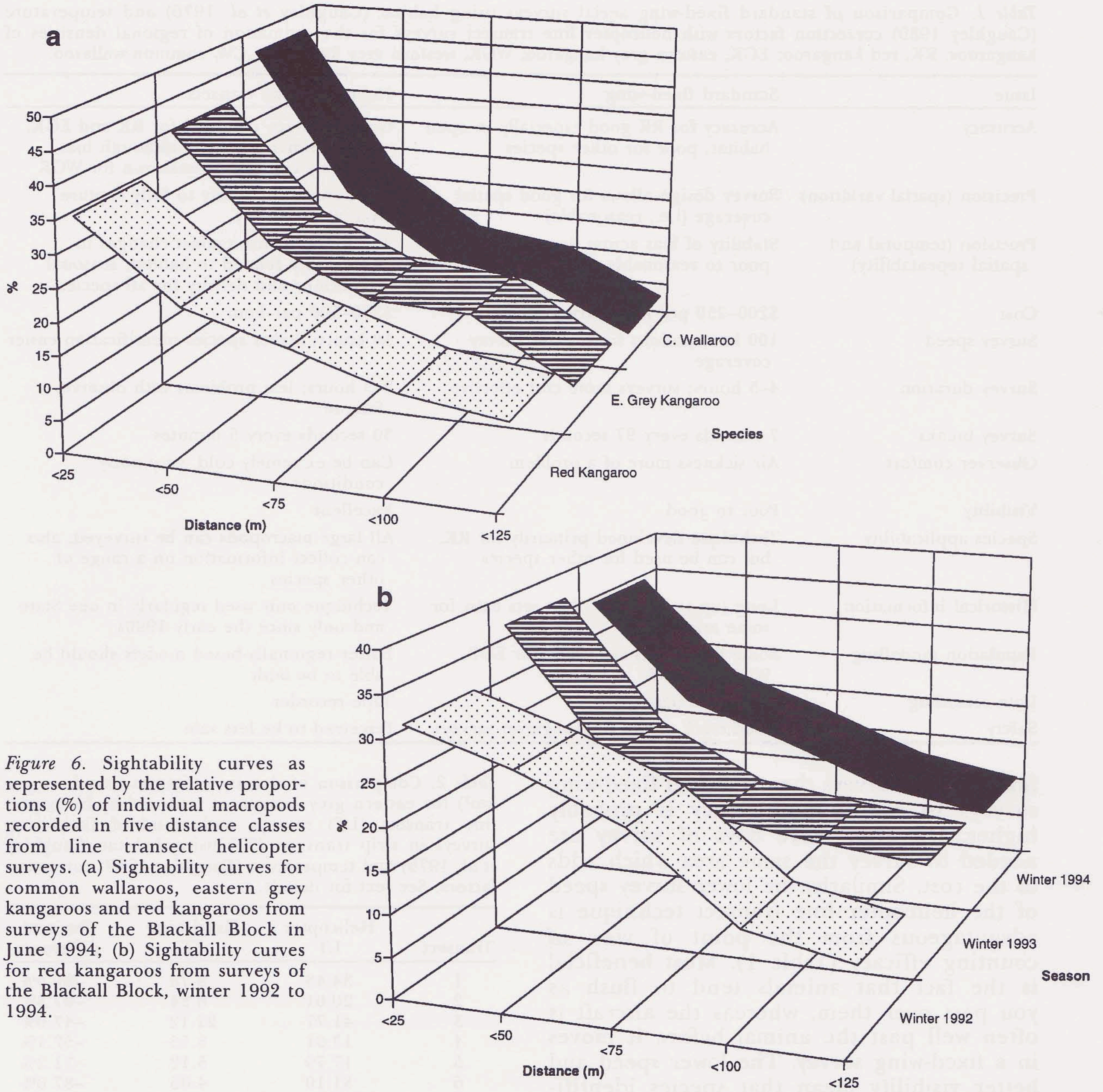


Figure 6. Sightability curves as represented by the relative proportions (%) of individual macropods recorded in five distance classes from line transect helicopter surveys. (a) Sightability curves for common wallaroos, eastern grey kangaroos and red kangaroos from surveys of the Blackall Block in June 1994; (b) Sightability curves for red kangaroos from surveys of the Blackall Block, winter 1992 to 1994.

and ventilation over a fixed-wing aircraft, which means there are fewer problems with airsickness and fatigue. However, in winter, when surveys are generally performed, it is extremely cold due to the high wind chill factor. Also, a helicopter is somewhat noisier than a fixed-wing aircraft.

The two survey platforms differ markedly in the visibility conditions for observers (Table 1). Perspex hazing may be a significant problem on the northern side of fixed-wing aircraft (Pople *et al.* 1993; Clancy and Pople, unpubl. data). This difference in sightability between sides can have a marked effect on the number of animals counted from either side of the plane and contributes to the lack of accuracy of counts. The impact this has on precision is less clear and it may well be able to be treated as a random effect (Pople *et al.* 1993). In a fixed-wing aircraft, observers' views are very restricted due to the small window areas and the requirement to look away from the sun which often means looking backwards. This undoubtedly impacts on counting efficiency, and may well add to the variation between observers. In the case of helicopters, observers' views are not in any way impeded as the doors are removed.

Shifting from the standard method will, in some cases, cause a problem with respect to long-term consistency of data sets (Table 1). For some areas, very large data series have

now been established and their value should not be underestimated. However, we should not stick with traditional methods just because they have been used in the past if better techniques are available.

As mentioned previously, the two different survey techniques necessitate a different approach to sampling. One potential advantage of a survey block design over blanket coverage of low sampling intensity is the improved ability to use the data to develop regional population models (Table 1). This is because the scale over which the sampling is being undertaken is more closely related to the scale over which population influences are occurring. The scale needs to be large enough to encompass changes in animal density due to movement, but not so large as to mask the effect of regional variations in environmental influences, such as rainfall.

There is a perceived difference in the safety of the two aircraft with a commonly held view being that helicopters are more dangerous than fixed-wing aircraft. It is difficult to assess actual risks involved in each survey type. A comparison of all reported accidents reported to the Bureau of Air Safety Investigation over the last five years suggests that helicopters may be more prone to serious accidents (Table 3). The comparison is based on small to medium sized helicopters and single engine Cessna aircraft (i.e., the types of aircraft commonly used for kangaroo surveys). While the actual number of accidents per hours flying is not known, it is apparent that when an incident does occur it is more likely to involve serious or fatal injury in the case of a helicopter. This comparison does not give a true reflection of risks involved as aircraft involved in incidents were undertaking a range of different tasks.

A breakdown the reasons for serious accidents reveals that some operations are inherently more dangerous than others (Table 4). Helicopters, because of their capabilities are more likely to be involved in such activities. For example, hitting power-lines is apparently a major risk in any low-level work; however, helicopters are commonly used for power line inspection and many of the reported incidents occurred during such surveys. With respect to kangaroo surveys, it is unlikely that there is any major difference in safety, given that the helicopter is operating well within its capabilities. To my knowledge there have been no incidents during either fixed-wing or helicopter surveys for kangaroos that have resulted in serious or fatal injury. There has, however, been an accident resulting in a fatality and injuries during a helicopter survey of rock-wallaby populations, a task involving greater risk than a kangaroo survey flown more than 150 ft above relatively flat terrain. Nevertheless, perceived differences in safety may become an issue in the recruitment of observers for a kangaroo survey using a helicopter.

Table 3. Number of recorded accidents and highest injury recorded per incident for Cessna-type (FW) aircraft and small to medium size helicopters for the period January 1993 to July 1998. See text for details.

	Highest recorded injury				
Aircraft	None	Minor	Serious	Fatal	Total
Helicopter	115 (55.3%)	41 (19.7%)	22 (10.6%)	30 (14.4%)	208
FW aircraft	273 (77.1%)	37 (10.5%)	16 (4.5%)	28 (7.9%)	354

Table 4. Recorded primary cause of accidents involving serious injury or death to aircraft occupants recorded for Cessna-type aircraft and small to medium size helicopters for the period January 1993 to July 1998. See text for details.

Cause	Helicopter	Fixed-wing	Total percentage
Engine failure (include rotor separation)	9	7	16.7%
Landing/take off	6	9	15.6%
Lifting gear failure	1	0	1.0%
Low-level manoeuvring (e.g., mustering, aerial shooting)	7	10	17.7%
Hit power lines (or other fixed low object)	17	8	26.0%
Poor weather (rain, high winds)	3	3	6.3%
Walked into rotor	1	0	1.0%
Other	1	1	2.1%
Unknown	7	6	13.5%
Total	52	44	

FUTURE CONSIDERATIONS FOR SURVEYS

Further comparative analyses of the two techniques need to be performed, taking into account the issues outlined above. The standard fixed-wing technique, as it currently stands, appears inadequate to address the specific survey requirements for some regions, especially for grey kangaroos in more timbered areas. This technique was essentially developed to survey red kangaroos in open country and cannot cope with the range of sightability conditions encountered across all species' distributions. The helicopter line transect technique may be more appropriate to use in many instances.

The decisions regarding the appropriate scale and survey intensity as well as cost considerations will be factors in determining the best technique to use for a given management programme. Technique selection should also be dependent on the level of precision and accuracy required. For both techniques more research needs to be undertaken on the inherent problems caused by variation in bias.

Observer comfort and safety needs to be taken seriously in the development of survey programmes. Optimal survey duration, number of breaks and other issues that impinge on observer efficiency have not been investigated in detail. Consideration should be given to use of tape recorders and, perhaps, computerized data recording devices in surveys to improve the observers' ability to concentrate on maintaining consistent and high levels of detection of target species.

There has been a tendency to assume that results obtained during specific research programmes into survey effectiveness will remain constant when surveys are done for management. However, it needs to be recognized that conditions often are not the same. Duration of survey sessions, number of sessions, ability to avoid poorer sightability conditions (e.g., cloud cover, temperature effects) and ability to select observers will often be different in routine management-based surveys than in surveys for research projects.

The review of causes for aircraft accidents provides pointers to increasing safety of all aerial surveys. For example, ensuring correct altitude is maintained, paying particular attention to aircraft maintenance regimes, not surveying in adverse weather conditions are important in minimizing risks to observers.

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